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Prospect of biodiesel in Pakistan

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ABSTRACT

Developing countries like Pakistan need continuous supply of cheap energy. It is common fear in today's world that fossil fuels will be depleted soon. The cost of energy is increasing continuously and is expected to be at its peak by 2050. Many technologically advanced countries are successfully using renewable energy sources for their energy needs, however, they still believe in the importance of fossil fuel. In renewable energy field, Pakistan is using hydropower for energy needs successfully, whereas project regarding solar and wind energy is in progress. Biomass, a renewable energy source, is gaining interest in many researchers because it produces similar type of fuel extracted from crude oil. Energy from biomasses only depends upon the availability of cheap raw material.

Biodiesel, which is produced by the reaction of vegetable oil and alcohol, can be used with same or with better performance in diesel engine. It is a clean fuel that causes less environment pollution as compared to petro diesel. High cost and non-continuous supply of vegetable oil is the main hurdle for its general acceptance. Many advanced countries have developed strategy for continuous supply of cheap price energy crops (source of biomass). Biodiesel is the only possible reciprocal to petro diesel or otherwise diesel engine will be useless after the depletion of crude oil.

In this study, biodiesel as an energy source has been discussed; this is indigenous diesel engine fuel and is beneficial for our environment, economy, and more importantly will increase the income of our farmers.

Contents

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1. Introduction

Oil and natural gas are the main sources of energy which provides mobility and power (electricity). Auto engine running on petro fuel has definitely raised the living standard of today's world. From energy to plastics, clothing, cosmetics, and many other products can be obtained from petro fuel (oil and gas). Transportation and power sector is the main consumer of petro fuel in Pakistan [1]. Fuel used in transportation industry has decreased the time of traveling and supported to transport heavy masses. Modern world is depended on the availability of uninterrupted energy which is serving us at home, work, and in leisure. Modern economy is surely depended on the availability of cheap fuel. Power (electricity) can be used for lighting, domestic appliances; television, computers and many more may be operated by petro fuel that have produced a huge comfort in life. In transportation industry, petro fuels are used in car, trucks, ships, airplanes to transport people and goods. Internationally fuel demands are increasing and same trend is expected in future [2].

Pakistan is a developing country and has limited resources of crude fuel oil. Pakistan is oil importing country. In fiscal year 2005/2006, Pakistan imported 8.6 million tons of crude oil [1]. Consumabled items (food stuff and other goods) are transported by trucks within country and their cost of transport may fluctuate due to price variation of fuel. Besides all these, in Pakistan auto industry is growing with approximately at rate of 25% per annum for the last 3 years and this trend may increase in future and thus will require more fuel. In short, prosperity and economy is dependent on the availability of cheap fuel.

It is highly expected that the energy (power and transportation) demand will increase by 53% by 2030 [2]. Developing countries like Pakistan will require approximately 50% more energy for power and transportation sector [1]. International Energy Outlook 2006 predicted that world petroleum demand will increase from the current 84.40 million barrels per day (bbl/d) to 116.00 million barrels per day by 2030 [3]. Proved oil reserves are depleting in 6 of the 11 members of the Organization of Petroleum Exporting Countries (OPEC); this may increase the cost of crude oil exorbitantly [2].

Pakistan has a capability of using renewable energy sources (solar, hydro, wind, tidal, energy, and biomass) whereas during 2005/2006 hydro energy (renewable energy) contributed 12.7% of the total energy mix [1]. Industrial sectors are growing within country which will increase the overall consumption of energy; however, for sustainable development the industry will require cheap energy whereas energy from oil and gas is costly especially for power generation. Pakistan has huge coal reserves and may use nuclear energy for power generation, which is cheaper than oil for producing power and may decrease overall load on crude oil imports.

2. Overview of energy situation

Pakistan's economy is growing after a long period of sluggishness and has made progress in the fields of agriculture, industry, and service sectors. The major energy consumption sectors of Pakistan are domestic, commercial, industrial, agricultural, transport and other government sectors. During fiscal year 2004/2005 country observed GDP growth of 8.4%; however, it decreased during fiscal year 2005/2006 and was 6.6% [4]. For sustainable economic growth, continuous supply of energy is necessary. Energy is used for power generation, continuous running of vehicles (engines) and for general heating purposes. The international monetary fund (IMF) and World Bank advised for energy generation projects and stressed on the privatization of state-owned oil exploration companies [4]. For instance, the Pakistani government has offered a 51% stake in Pakistan Petroleum Limited (PPL), as well as a 54% stake in Pakistan State Oil (PSO) [1]. PPL owns the Sui fields in Balochistan (Pakistan), as well as exploration interests in 22 blocks, while PSO holds a majority share in the domestic diesel fuel market with more than 3800 retail outlets [1]. In November 2006, Pakistan issued shares from OGDCL for the equivalent of 15% of the NOCs (National Oil Companies) capitalization [1].

2.1. Energy sources of power generation

Today power is the basic requirement of every citizen and its requirement is almost as important as food items. There are a number of possible ways to generate power from renewable and nonrenewable sources. In present situation hydro energy is the only renewable energy used while main portion of energy mix is dependent on fossil fuel [1]. Pakistan is investigating the possible ways to generate power from renewable energy sources so that it can share 10% of energy mix and have already signed project with Turky-based Zorlue Energji Grubu for wind energy and will be operable after 2008 [4]. According to the Pakistan Energy Yearbook, natural gas is currently the country's largest power energy source, making up to 50% of Pakistan's energy mix in fiscal year 2005/2006 as shown in Table 1 [1].

2.1.1. Oil and natural gas energy

According to oil and gas journal, Pakistan's proved reserves of oil are about 300 millions barrels [1]. Since the 1980s, Pakistan has not explored new oil fields due to which oil production has remained fairly flat, at around 60,000 barrels per day [1]. Due to this, Pakistan is a crude oil importing country and imports oil mainly from Middle East especially from Saudi Arabia [1]. Auto industry and power sector are growing within country and therefore the demand of crude oil is continuously increasing with the passage of time. Pakistan state bank paid $6.7 billion for oil imports during 2005/2006 [1].

Table 1
Pakistan energy supply mix, 2005/2006.

S. no	Energy source	Production (million tons)	Percentage
1	Oil	16.44	28.4
2	Natural gas	29.18	50.4
3	Coal	4.05	7.0
4	LPG	0.23	0.4
5	Nuclear	0.57	1.0
6	Hydroelectricity	7.35	12.7

In case of gas, Pakistan had 28 trillion cubic feet of natural gas reserves during the fiscal year 2005/2006 [1]. In 2004, Pakistan produced and consumed 968 billion cubic feet (Bcf). However, natural gas production is expected to decrease over the next 15–25 years period, while natural gas demand is expected to increase [1]. Feasibility of different projects is under consideration for oil and gas import (Fig. 1).

2.1.2. Coal energy

Coal currently plays a minor role in Pakistan's energy mix, although the country contains an estimated 180 billion tons of proven recoverable reserves, which stand fifth in world [1]. In 2004, Pakistan imported 1.7 million short tons and indigenously produced 3.5 million short tons to satisfy its demand. In the province of sindh (Pakistan), desert of Tharparker, large deposit of coal reserves having amount 175 billion tons of good quality have been found [1]. China and Korea have shown great interest to build power plants based on coal reserves. However, several factors have hindered the development of the Thar coal reserves, including the depth and moisture level of the lignite reserves, a scarcity of fresh water, and a lack of road and power infrastructure. Presently coal imports are high as compared to indigenous production to satisfy its need (Fig. 2).

2.1.3. Nuclear energy

Currently nuclear energy is contributing 1.2% in energy mix by running two nuclear power plants; however, work on the third power plant (Chasma-2) is on final phase. Chasma-1 and Chasma-2 are of 300 MW capacities while Kanupp is capable of producing 125 MW energy [1].

2.1.4. Renewable energy

Renewable energy has a promising potential for energy generation; however, these should be seen as supplementary resources and not alternatives. Solar, wind, biomass and hydel resources are current research area of modern researchers. Hydro power (renewable energy) is one of the cheapest sources of power generation; however, requires huge capital cost for building dams [1]. During 2005/2006 contributed 12.7% to total energy mix. Power generating capacity may be disturbed by periodic droughts and sustainable plan should be present to overcome drought condition [1]. Thebela power plant is one of the largest water reservoirs of Asia and has installed a capacity of 3046 MW. Additional hydroelectric plants in operation include Mangla (1000 MW), Warsak (240 MW), and Chashma (184 MW). New projects such as Basha and Kalabagh dam have been launched to increase the overall generating capacity of power.

Pakistan has unique geographical location and favorable climate for the production of solar and wind energy generation. Presently there is a lack of state policy for the generation of solar and wind energy. Biomass energy is being utilized in rural areas

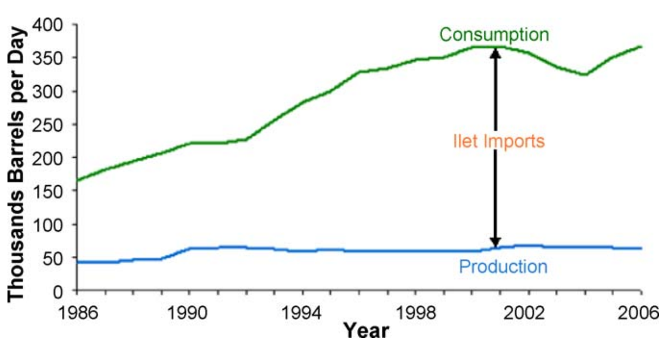


Fig. 1. Pakistan oil consumption and production, 1986–2006.

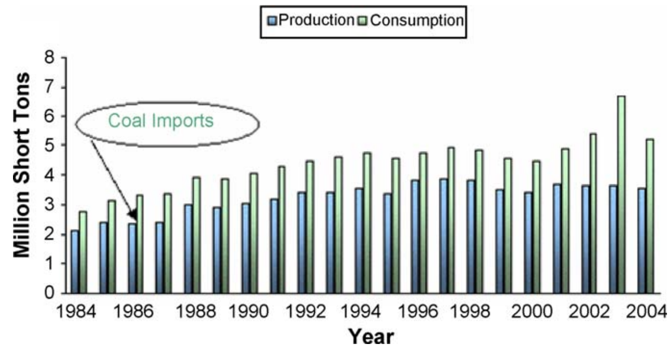


Fig. 2. Pakistan's coal consumption and production, 1984–2004.

with very low efficiency due to non-scientific conventional technologies. Wood, animal waste and crop waste are being used for domestic fuel mainly for heating purposes.

2.2. Energy source for auto ignition engines (transport sector)

Main consumer of crude oil is combustion engines [1]. Transport industry (buses, cars, etc.) can only accept petroleum fuel oil for its energy generation. Price of crude oils is increasing with passing time due to the increase in demand and decrease in supply. According to researchers high prices of crude oil will be observed after 2050 [2]. Renewable energy sources such as ethanol and methyl ester (biodiesel) are only reciprocal to present engine technology for smooth running of vehicle. During fiscal year 2006/2007, the consumption of petroleum-based energy was 16.85 million tons [1]. Transport sector was the main user of crude oil followed by power sector as described in Table 2 [1].

3. Environmental drawbacks of petro fuel

Vehicles are the main users of diesel and petrol due to which the quality of air is degrading. Old models of diesel engine are still in use within country and are main contributors to air pollution. Many cities of Pakistan have air pollution quite high as compared to WHO standards and the average increase of SO_2 in air has increased to 23-folds over the past 20 years [5]. The losses caused due to air pollution in terms of health and care is approximately about 500 million dollars per year while the diseases due to air pollution are increasing [3]. Asthma and lung diseases are caused by SO_2 and it also causes acid rain [6]. Pollutants like CO, CO_2, Ozone, NO_x, and many volatile organic matters are disturbing air quality at alarming levels in major cities of Pakistan [7].

4. Definition of biodiesel

Biodiesel is currently defined as technical regulation set by European Union as EN14214 or by USA as ASTM 6751-02 [8]. Biodiesel is the commercial name of diesel engine fuel produced by transesterification of vegetable oil or fats with alcohol in the presence of catalyst which can be acid or base. Biodiesel is

Table 2
Petroleum products consumption by sector, 2006–2007.

S. no	Consumption sector	Consumed energy (million tons)	Percentage
1	Transport	7.98	47.4
2	Power	6.74	40.0
3	Industry	1.60	9.5
4	Domestic	0.10	0.6
5	Government	0.32	1.9
6	Agriculture	0.10	0.6

biodegradable, non-toxic and environment friendly as compared to petro diesel and can run diesel engine with same or better performance as compared to normal petro diesel fuel. Vegetable oil/fats and alcohol (methanol, ethanol, and butanol) can be used for transesterification reaction [9]. Many researchers have found that basic catalyzed reactions are much faster and economical than acid-catalyzed reaction [9–12]. The transesterification reaction is shown in Fig. 3.

where R^1, R^2, R^3, R^4 are various alkyl groups. Ester formed has approximately the same properties like normal petro diesel [13].

5. Feasibility of biodiesel in Pakistan

Generally vegetable oil can be reacted with methanol or ethanol for biodiesel production. Methanol is more generally used in world market because it is relatively cheaper than ethanol. Methanol is produced from coal and reserves of coal in Pakistan are 180 billion tons, 5th largest in world [1]. Presently ethanol production is at high rate and there are 76 sugar mills in the country, with a crushing capacity of 300,000 tons of cane per day [14]. Cane molasses is the main by-product which is used for ethanol production. There are 21 distillery units in Pakistan with a capacity to process 2 million tons of molasses to produce 400,000 tons of ethanol; therefore, it means that excess ethanol can be either for gasohol purpose or for biodiesel production [15]. These 21 distilleries are working within country with a production capacity of 400,000 tons, its consumption and export is about 80,200 and yet has surplus ethanol, which is 318,000 tons [15]. In case of ethanol needs for biodiesel production, sufficient stock is available and its production can be increased. Generally, the catalyst for biodiesel production is Caustic soda whereas production is presently enough for country's needs and its production can be increased due to the presence of huge reserves of sodium chloride (raw material for Caustic soda) [16,17]. Caustic soda solutions are produced as a co-product with chlorine electrolytically by three technologies: mercury cells, membrane cells, and diaphragm cells. Each of these processes utilizes sodium chloride salt as the primary raw material. The salt is electrolytically split using direct current (DC) electricity, resulting in chlorine and an available sodium ion (Na+) that is reacted with water in the cell to make Caustic soda and by-product hydrogen [18].

Pakistan is an agriculture country with 70% of its population working in farm fields. According to a map prepared by the Soil Survey of Pakistan (published in 1988), nine major land use classes have been identified as described in Table 3 [19].

Table 3
Land use categories of Pakistan (000′ ha).

S. no	Land use type	Area, 1000 ha
1	Agriculture	21,733
2	Rangelands	25,475
3	Coniferous forests	1,353
4	Irrigated plantations	80
5	Scrub forests	796
6	Riverain forests	239
7	Waste lands including areas under ice and snow	28,501
8	Water bodies (rivers only)	1,274
9	Others	159
10	Total	79,610

Agriculture fields are scattered throughout Pakistan as shown by yellow color [19]. It is also advisable not to disturb the eco system, by converting other types of land such as rangelands into energy crops field. The total amount of unused land is about 28 million hectare [19]. This large area of land is unproductive due to water shortage, severe heat, and saline soil (Fig. 4).

It is, however, unfortunate that despite having rich lands, Pakistan which essentially has an identity of an agriculture-based economy has to rely on imports for edible oil, wheat and milk [14]. Neighboring country, India is very much successful in producing biodiesel from jatropha plant seeds, whereas jatropha plants can be cultivated in Pakistan especially in saline soil with less quantity of water and it can also withstand high temperature [20]. Jatropha can yield up to two tons of biodiesel fuel per year per hectare. If in ideal condition Pakistan utilizes all uncultivated land for biodiesel production, then it means we can produce 56 million tons of biodiesel per year, a huge amount, while present need of diesel fuel is about 8.5 million tons [1]. Currently Pakistan's need of vegetable oil (edible oil) is about 1.55 million tons whereas domestic production of oil is about 620,000 tons, thus short of 930,000 tons [21]. In domestic production, major share comes from cottonseed contributing 75% of local production. Rapeseed, mustard and canola contribute 15%, whereas sunflower, soybean, safflower and corn contribute the remaining 10%. Government of Pakistan is very serious to increase the production of edible oil and established the department of Pakistan Oilseed Development Board [14].

Historically animal fats were used in Pakistan, having been replaced by vegetable oil due to an increase in population and per capita consumption. Due to diverse ecological conditions of Pakistan, lucky to have over a dozen oil seed crops of which it can afford to grow one or the other in all seasons of the year. Depending upon the historical cultivation and production the oil seed crops were classified into conventional (i.e. traditional), non-conventional, industrial and wild crops [22] (Table 4).

In short, land is available for the cultivation of energy crops. Pakistan's need of energy is growing and 10% growth of energy (including power and transport sector) is observed every year [23]. Therefore biodiesel project is feasible and has very booming future in Pakistan, raw material for biodiesel production is available, and more importantly Government of Pakistan is very serious in energy generation.

6. Production of biodiesel

Currently Pakistan is unable to produce indigenously enough quantity for edible oil to cover its domestic need; therefore,

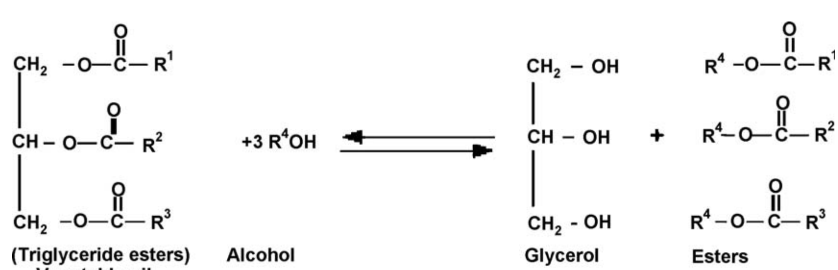


Fig. 3. Biodiesel esterification reaction.

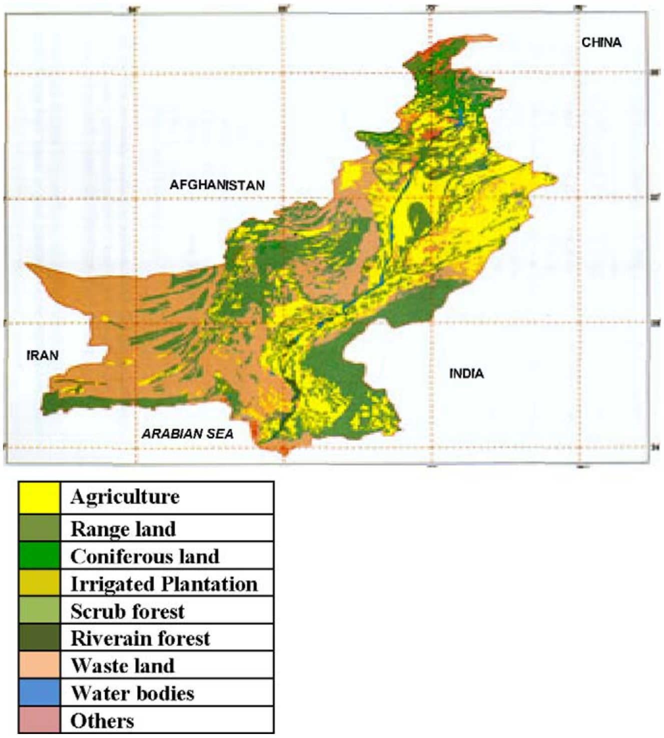


Fig. 4. Agriculture and land use.

imports vegetable oil. Common sources which are used to produce edible oil in local refinery are palmolein, soybean oil, corn oil, cottonseed oil, rapeseed oil, sunflower oil and canola oil. The basic chemical structure of vegetable oil (triglycerides) is same, however may have different fatty acid chains. Fatty acid chain may have double or single bond, if double bond is present, it will be in liquid state at normal atmospheric condition while oil in which there is single bond then it will be in solid state at normal condition. Different fatty acid chains which are present in vegetable oil are palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2) and linolenic (18:3). The first digit of colon shows number of carbon atoms while the second digit describes number of bonds. Normal vegetable may have a series of different fatty acid chains. Table 5 shows the percentages of each fatty acid chain present in common oils and fats [24].

Vegetable oils cannot be easily used as diesel engine fuel therefore it is converted to more efficient form through transesterification process, which is biodiesel (methyl ester). Biodiesel is biodegradable, very efficient and most importantly environment friendly fuel as compared to petro diesel. Fats or oil reacts with alcohol to form esters and glycerol. Acid or base catalyst is used to improve the mixing of triglycerides and alcohol which increases the reaction rate and yield. Any alcohol such as methanol, ethanol or propanol can be used depending upon the quality and economy. The ester produce has viscosity very near to petro diesel and hence there is no need to modify the existing engine. Biodiesel can be easily mixed with the petro diesel as compared to vegetable oil.

Table 4
Categories of vegetable oil seeds.

Conventional	Non-conventional	Industrial	Wild crops
Rape seeds	Sun flower	Linseed	Pongame tree
Ground NUT	Soybean	Castor beans	Olive tree
Sesame seeds	Safflower	Cotton seeds	Hemp oil
Rocket seeds			Oat seeds
			Milk thistle
			Carthamus seeds

Biodiesel has higher flash point as compared to petro diesel which means that it is safer to use Biodiesel and at the same time it has higher or same cetane number which is required for fuel property. Biodiesel when mixed with petro diesel increases the cetane number. Petro diesel has caloric value very close to biodiesel. In short the flash point, density, pour point, cetane number, calorific value are in very close range to petro diesel. Diesel engine can perform satisfactory for long run on biodiesel without any hardware modifications. Pure biodiesel is shown in Fig. 5.

The yield of biodiesel can be improved by the following parameters.

6.1. Reaction temperature

Higher the temperature the higher will be the rate of reaction, but it will be up to certain limit. Reaction is carried out near the boiling point of methanol at room pressure so that alcohol must be present in liquid form and it can react efficiently with vegetable oil; however, in number of researches it is founded that the best esterification reactions are observed between 60 and 70 °C [25,9,10].

6.2. Molar ratio of alcohol and oil

Molar ratio effects the yield of chemical reaction and also the reaction rate. According to stoichiometry of the transesterification reaction requires 3 mol of alcohol per mole of triglyceride to give 3 mol of fatty esters and 1 mol of glycerol. If higher concentration

Table 5
Composition of fatty acids in different oil.

Oil and fat	14:0	16:0	18:0	18:1	18:2	18:3	20:0	22:1
Soybean		6–10	2–5	20–30	50–60	5–11		
Corn	1–2	8–12	2–5	19–49	34–62	Trace		
Peanut		8–9	2–3	50–65	20–30			
Olive		9–10	2–3	73–84	10–12	Trace		
Cottenseed	0–2	20–25	1–2	23–25	40–50	Trace		
Hi linoleic safflower		5.9	1.5	8.8	83.8			
Hi oleic safflower		4.8	1.4	74.1	19.7			
Hi oleic rapeseed		4.3	1.3	59.9	21.1	32.2		
Hi erucic rapeseed		3.0	0.8	13.1	14.1	9.7	7.4	50.7
Butter	7–10	24–26	10–13	28–31	1–2.5	0.2–0.5		
Lard	1–2	28–30	12–18	40–50	7–13	0–1		
Tallow	3–6	24–32	24–32	37–43	2–3			
Linseed oil		4–7	4–7	25–40	35–40	25–60		
Yellow grease	2.43	23.24	23.24	44.32	6.97	0.67		



Fig. 5. Pure biodiesel.

of product is required then we have to add more reactant either alcohol or triglycerides. To shift the transesterification reaction to the right, it is necessary to use either excess of alcohol or remove one of the products from the reaction mixture. The reaction rate is high when methanol is used in 100% excess. A molar ratio of 6:1 is normally used in industrial processes to obtain methyl ester yields higher than 98% by weight [12].

6.3. Catalyst

Alkali or acidic catalyst can be used for transesterification reaction. Generally alkali catalyst is more favorable than acidic catalyst because it is less corrosive than the acidic catalyst [9]. Sodium hydroxide or potassium hydroxide is used as a catalyst. Sodium hydroxide can give higher yields by using 1% of the total weight of vegetable oil. The reaction can be catalyzed by alkalis, acids, or enzymes. The alkalis include NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium propoxide and sodium butoxide. Sulphuric acid, sulfonic acids and hydrochloric acid are usually used as acid catalysts. Lipases also can be used as biocatalysts.

6.4. Reaction time

The conversion of vegetable oil to biodiesel is high at start but with the passage of time its rate decreases due to less driving force. Freedman transesterified peanut, cottonseed, sunflower and soybean oils with methanol with ratio to oil of 6:1, 0.5% sodium methoxide catalyst and at 60 °C [27]. An approximate yield of 80% was observed after 1 min for soybean and sunflower oils [27]. After 1 h, the conversions were almost the same for all four oils (93–98%). Ma and Hanna studied the effect of reaction time on transesterification of beef tallow with methanol [9]. The reaction was very slow during the first minute due to the mixing and dispersion of methanol into beef tallow. From 1 to 5 min, the reaction proceeded very fast. The apparent yield of beef tallow methyl esters surged from 1% to 38% [9].

6.5. Presence of moisture and free fatty acids (FFA)

Vegetable oil and alcohol used for the production of biodiesel should be free from moisture and free fatty acids. Water will react with triglycerides and will form free fatty acid which will react with alkali catalyst and will produce soap. The soap is undesirable product because it creates difficulties to separate biodiesel and glycerol and also it produces gum when burnt in cylinder. Moisture can be removed using silica gel. The glyceride should have an acid value less than 1 and all reactants should be substantially anhydrous [13]. For high free fatty acid value more NaOH is required to neutralize the free fatty acid.

7. Comparison between petro diesel and biodiesel

Biodiesel as fuel can compete with the existing petro diesel fuel. Biodiesel is compared with petro diesel in number of categories such as energy content, hazardous material rating, health and social impacts, and engine performance rating.

7.1. Carbon life cycle

Oxygen is present in biodiesel which is about 11% due to which it has better combustion properties and therefore has less tail emissions. Carbon life cycle involves all steps including its production. Plantation (energy crops) is helpful in reducing CO_2 in atmosphere but biodiesel burnt will again rise CO_2 concentration but in fewer amounts as compared to petro diesel hence causing overall reduction of CO_2 concentration in open atmosphere. Biodiesel produces slightly increased NO_x emissions while significantly reducing other major emissions. Environmental protection agency (USA) analyzed the emission of soya oil, rape seed oil, and animal fats and found increase amounts of NO_x emissions while reduction in other emissions [26] (Table 6).

7.2. Environmental benefits

A huge investment is required for the better health of citizens. Unfortunately diesel engines are the high particulate emission source (79%) [22]. Its emissions consist of a wide range of organic and inorganic compounds. These particles have hundreds of chemicals absorbed onto their surfaces, including many known, and suspected, mutagens and carcinogens. NO_x, SO_x, PM, are general emission of petro diesel fuel which can be greatly reduced by using biodiesel fuel except NO_x.

Green house gases are also the main reason for global warming. Biodiesel as fuel can decrease the rate of global warming by reducing the emission of green house gases and besides this used vegetable oil was considered waste and had disposal problem earlier and can be reused as fuel again.

A great reduction is observed in smog forming pollutants. It evolves much less toxic pollutants as compared to petro diesel as shown in Table 7. Data of B20 and B100 are provided for overall view [27].

The toxic pollutant polycyclic aromatic hydrocarbons (PAH) and NPAH (nitrated PAH) has a great reduction [28] (Table 8).

Table 6
Comparative emissions of vegetable oils.

	Soy oil		Rapeseed oil		Animal fats	
	20%	100%	20%	100%	20%	100%
NO_x	+3.1	+15.4	+2.4	+12.0	+0.6	+3.3
PM	−6.8	−34.0	Note reported	Note reported	−10.3	−48.7
CO	−3.7	−17.2	−5.5	−25.1	−8.7	−40.3

Table 7
Smog forming pollutants.

Smog forming pollutant	B100	B20
Unburned hydrocarbons: (HC)	67% reduction	14% reduction
Carbon monoxide (CO)	48% reduction	10% reduction
Particle matter (PM)	47% reduction	10% reduction
Sulphur (SO_x)	100% reduction	20% reduction
Nitrogen oxide (NO_x)	10% reduction	2% increase

Table 8
Toxic emissions.

Smog forming pollutant	B100	B20
Polycyclic aromatic hydrocarbons (PAH)	80% reduction w/B100	13% reduction w/B20
NPAH (nitrated PAH)	90% reduction w/B100	50% reduction w/B20

7.3. Hazardous rating comparison

Biodiesel in nature is non-hazardous as compared to petro diesel. Its flash point is high therefore safe to use. Biodiesel is biodegradable and 95% of it can be degraded in 28 days [28]. Biodiesel in blend form for example as B20 can degrade faster that normal petro diesel. Hazardous comparison between petro diesel and biodiesel is shown in Table 9 [28].

7.4. Social benefits

Pakistan is an agriculture country with 70% of its population earn from agriculture for their livelihood. They can uplift their standard of living by producing oil seed generating crops in their field. Small scale biodiesel production facility can be designed with less investment and will be helpful in providing biodiesel fuel for their agriculture machinery. Those areas of land which were useless due to water shortage or soil salinity can be used for oil crops. Government pays a huge bill for its crude oil import thus giving no benefit to its local economy. If farmers are able to generate energy crops then they are giving benefits not only to themselves but also to overall economy of country.

In Europe biodiesel plants are being developed as large conglomerate entities. The produced fuel is then transported back to widely dispersed distribution depots. Germany is very successful example and is increasing production capacities.

7.5. Engine performance

Diesel engine has the right to decide whether biodiesel is good or not. After going through a number of experimental tests the scientist agreed upon the better or comparable performance of biodiesel fuel. The generalized performance is given in Table 10 [29].

Table 9
Biodiesel/diesel hazard comparison.

Property	Biodiesel	Petroleum diesel
Biodegradability	Readily biodegrades 3+ times faster from diesel	Poor biodegradability
Flashpoint	150 °C	51.7 °C
Toxicity	Essentially non-toxic	Highly toxic
Spill haxard	Benign. Biodeisel is safe to handle with no dangerous fumes. No training required for handling	Dangerous and toxic. Hazmat training required

8. Strategy for the production of biodiesel in Pakistan

The issue of climate change and energy security has become the priority in recent times. The main principal for viable biofuels plan is depended on the availability of raw materials. The Economic Coordination Committee (ECC) of the Federal Cabinet has approved the policy for the use of biodiesel as an alternative fuel in its meeting held on 15 February 2008. The strategy was formulated by the Alternative Energy Development [22]. Main feature are as follows:

- Ministry of Water & Power in coordination with AEDB shall be the apex coordinating and facilitating body for the National Bio-Diesel Programme.
- Gradual introduction of biodiesel fuel blends with petroleum diesel so as to achieve a minimum share of 5% by volume of the total diesel consumption in the country by 2015 and 10% by 2025.
- Oil Marketing Companies (OMCs) to purchase Bio-Diesel (B-100) from biodiesel manufacturers; and sell this Bio-Diesel blended with Petroleum Diesel (starting with B-5) at their points of sale.
- Ministry of Petroleum & Natural Resources shall come up with the fuel quality standards for B-100 and blends up to B-20.
- OGRA shall regulate the pricing mechanism of various blends of Bio-Diesel (B-5, B-10, etc.) and ensure its cost-competitiveness with petroleum diesel.
- All imported plant, machinery, equipment and selective raw material, e.g. Jatropha, for use in the production of Bio-Diesel shall be exempted from customs duty, income tax and sales tax.

9. Conclusion and recommendations

At present time the only possible alternative fuel for ignition engines can be biodiesel (methyl ester) for diesel engines and ethanol for gasoline engine. With increasing population, the need of edible oil is increasing and at the same time energy needed for ignition engines is also increasing. During 1960s the production of edible oil was sufficient for its population but now Pakistan is importing edible oil. The one single step solution to this problem is to increase the production of vegetable oil producing seeds. Pakistan is an agriculture country with 70% of its population working in farm fields so therefore no problem in case of human resource. The production of biodiesel is simple and easy technology. Biodiesel production is a focused research area of many countries including countries like Germany, USA, etc.

Table 10
Engine performance comparison.

Property	Biodiesel	Petroleum diesel (CARB low-sulphur)
Engine efficiency	A 10–15 point higher cetane rating provides improved combustion, a smoother running engine, and quieter operation	Runs slightly rougher and louder with increased "knocking"
Energy density	Approximately 10% less at 950 Btu/cu.ft	Approximately 10% more at 1058 Btu/cu.ft
Fuel consumption	In in-use engines, fuel economy substantially improves and is maintained due to continuous cleaning effects of biodiesel. Clean fuel lines, injectors, and other engine components will improve combustion	Comparable in new engines
Horsepower and torque	Comparable	Comparable. Acceleration is slightly better due to a lower viscosity
Lubricity	Biodiesel much higher lubricity rating provides for increased engine life. A B2 blend will increase diesel lubricity by up to 65%. This will be critical for engines as pending regulations require diesel fuel sulphur levels be reduced	Diesel's lubricity is the result of its sulphur content. Once the sulphur is removed, expensive chemical additives are needed to increase the lubricity

Presently biodiesel seems to be highly costly as compared to petro diesel; however, there will be no other solution when petro diesel runs out.

Best strategy is to use all unutilized free land for the production of energy crops. If there is fear for enough quantity of energy crops, investor will never invest in such business. Success of biodiesel project will depend on the following main areas:

- Cheap feed stock availability.
- Continuous supply of feed stock.
- Pilot scale biodiesel production for experimentation.
- R and D facility.
- Financial help to new investors.

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